High efficiency GaN/$Al_xGa_{1-x}N$ multi quantum well light emitter on low-dislocation density $Al_xGa_{1-x}N$

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High-quality $Al_xGa_{1-x}N$ is unavoidable for the fabrication of UV-opto-electronic devices in the next generation, because the $Al_xGa_{1-x}N$ ternary alloys have direct wide bandgaps ranging from 3.4 to 6.2 eV. Very recently, we succeeded in growing crack-free, thick and high-crystalline quality $Al_xGa_{1-x}N$ by low-temperature AlN interlayer technique [1]. High-sensitivity flame sensor was demonstrated in this technique [2]. Detailed transmission electron microscopic (TEM) study showed that the $Al_xGa_{1-x}N$ films of pure screw-type and mixed-type dislocations can be reduced, while high-density pure edge-type dislocation was contained as high as 10^9 cm^{-2} in this films [3]. Fabrication of highly luminescent $Al_xGa_{1-x}N$ was still one of the critical issues in nitride.

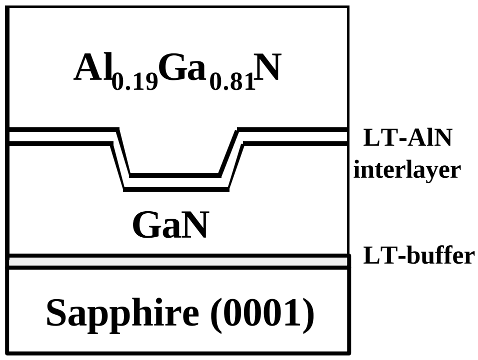

Fig. 1 Schematic view of Sample A

We report on the new growth technique of fabricating low dislocation density and crack-free $Al_xGa_{1-x}N$. The samples were grown on sapphire (0001) substrate by organometallic vapor-phase epitaxy. Figure 1 schematically shows the structure (Sample A). After depositing low temperature AlN buffer layer about 20 nm in thickness at 500 °C, GaN about 3 μm in thickness was grown at 1,100 °C. Trench along direction were fabricated by conventional photolithography and reactive ion etching technique. Widths of the trench, space between trench and the depth of the trench were about 5 μm, 5 μm and 1 μm, respectively. Next, AlN about 20 nm was deposited at 500 °C as a low temperature deposited interlayer. After that, $Al_{0.19}Ga_{0.81}N$ was grown at 1,100 °C. After 5 μm growth, smooth and crack-free surface was obtained. Cracks always generate when $Al_{0.19}Ga_{0.81}N$ having the same thickness was directly grown on GaN. Figure 2 shows cross sectional TEM image of the sample. In the trench region, many threading dislocations bend toward center of the trench.

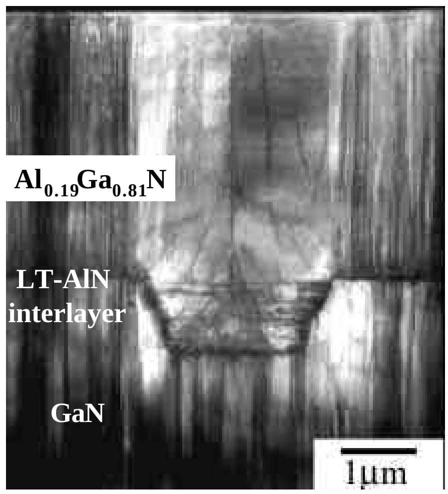

Fig. 2 Cross sectional TEM image of Sample A

Density of threading dislocation above trench is lower than 10^8 cm^{-2}. Therefore, threading dislocation is reduced by a factor of more than ten compared with that of $Al_xGa_{1-x}N$ grown by low temperature interlayer technique and more than two orders of magnitude compared with that of $Al_xGa_{1-x}N$ directly grown on low temperature deposited buffer layer.

Next, in order to demonstrate the effect of dislocation reduction on the luminescence properties of GaN and/or $Al_xGa_{1-x}N$, GaN/$Al_{0.08}Ga_{0.82}N$ MQW having five 3 nm-thick GaN wells and 8 nm-thick Si doped $Al_{0.08}Ga_{0.82}N$ barriers were grown on the $Al_{0.22}Ga_{0.78}N$ film. Figure 3 schematically shows the structure (Sample B). This sample was characterized by microscopic-photoluminescence (micro-PL) at room temperature (RT). Samples were excited by focused He-Cd laser (325 nm) with a diameter of 1 μm. Figure 4 shows micro-PL intensity mapping. Insert shows the spectra from bright and dark region. PL intensity from the MQW on the trench region is higher than that on rest-of-trench region by a factor of ten. The intensity is also stronger than that of MQW on $Al_xGa_{1-x}N$ directly grown on low temperature buffer layer by more than two orders of magnitude. These results show that combination of low temperature interlayer technique and the lateral seeding epitaxy realized the crack-free and low dislocation density $Al_xGa_{1-x}N$ simultaneously, which must be quite effective in fabricating high-efficiency UV emitters. Performance of the UV-LEDs fabricated by this newly developed technique will be discussed.

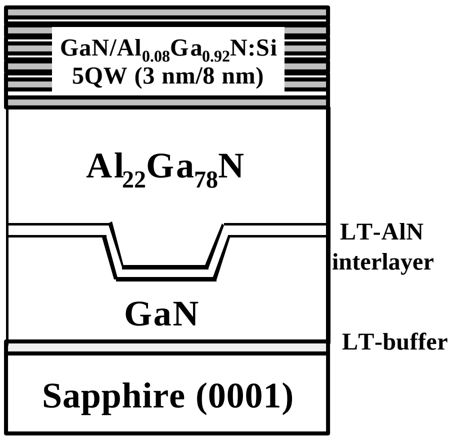

Fig. 3 Schematic view of Sample B

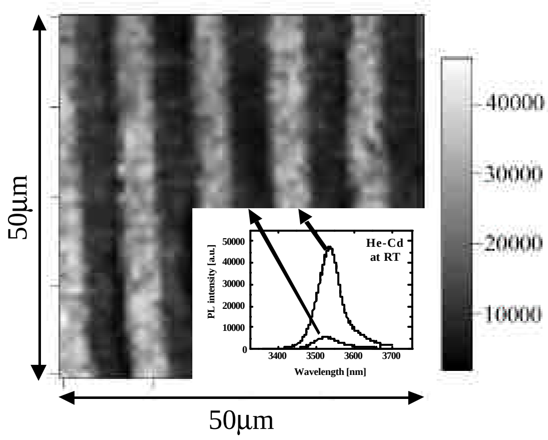

Fig. 4 Micro-PL intensity mapping and PL spectra of Sample B

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